Optimal Portfolio Methodology for Assessing Distributed Energy Resources Benefits for the Energynet[SM]

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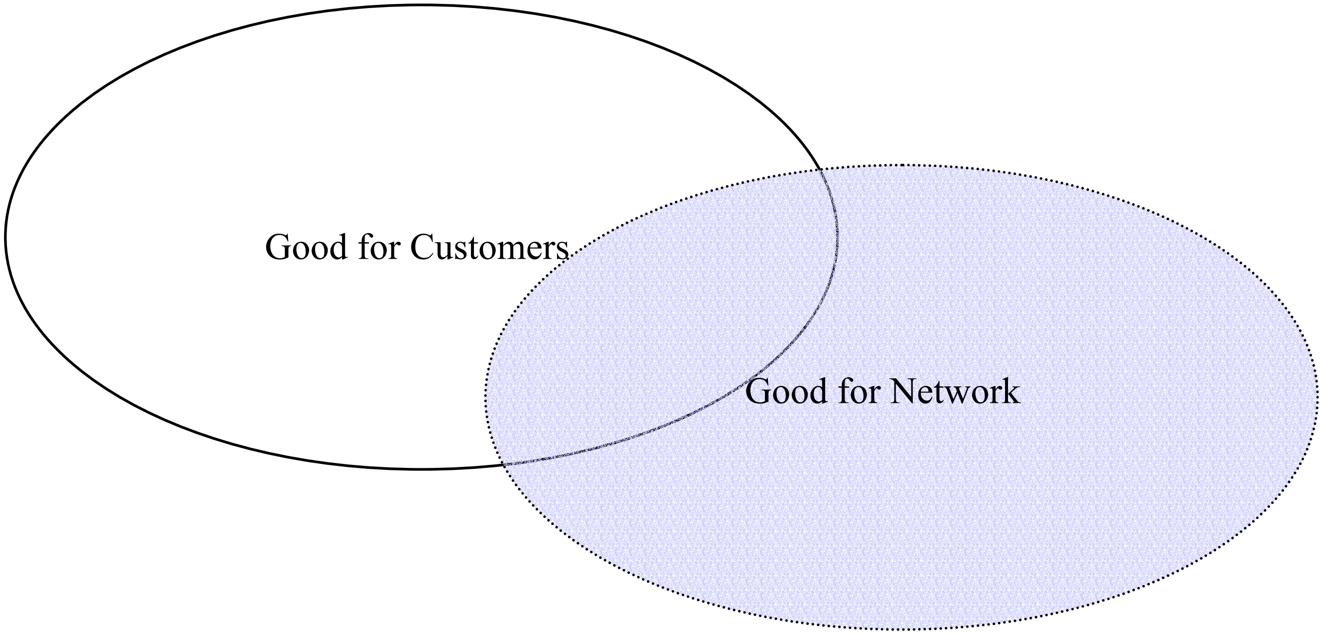
Pressing Questions

- **What *is* the potential for Distributed Energy Resources (DER) to enhance performance of the power delivery network?**
- **Can benefits be reliably measured and valued?**
- **What are the specific location, size, and operating profile of DER projects that contribute the most to network performance?**
- **What are the most consequential barriers to these "beneficial" DER projects?**
- **Can utilities provide incentives for "beneficial" DER projects by sharing value rather than shifting costs?**

Why look only at network benefits of DER?



- **End-use customers and network operators (utilities) are independent stakeholders with different interests.**
- **If network (utility) benefits of DER can be quantified and priced, their value can be shared with customers.**

What's Different

- **Analyze the power delivery network where DER projects are actually connected**
  - with transmission and distribution as an *integrated* power delivery network (Energynet).

- **Consider DR *and* DG *and* capacitors as available DER options.**

- **Observe the impacts of DER on a broad set of network performance indicators.**
  - Voltage profile improvement
  - Reduced reactive power flows
  - Reduced electrical losses
  - Stability and power quality improvement
  - Avoided or deferred network additions

- **Optimal Technologies' AEMPFAST® network optimization software.**
  - Direct voltage optimization => precise placement of *hundreds* of real and reactive capacity additions through DER.

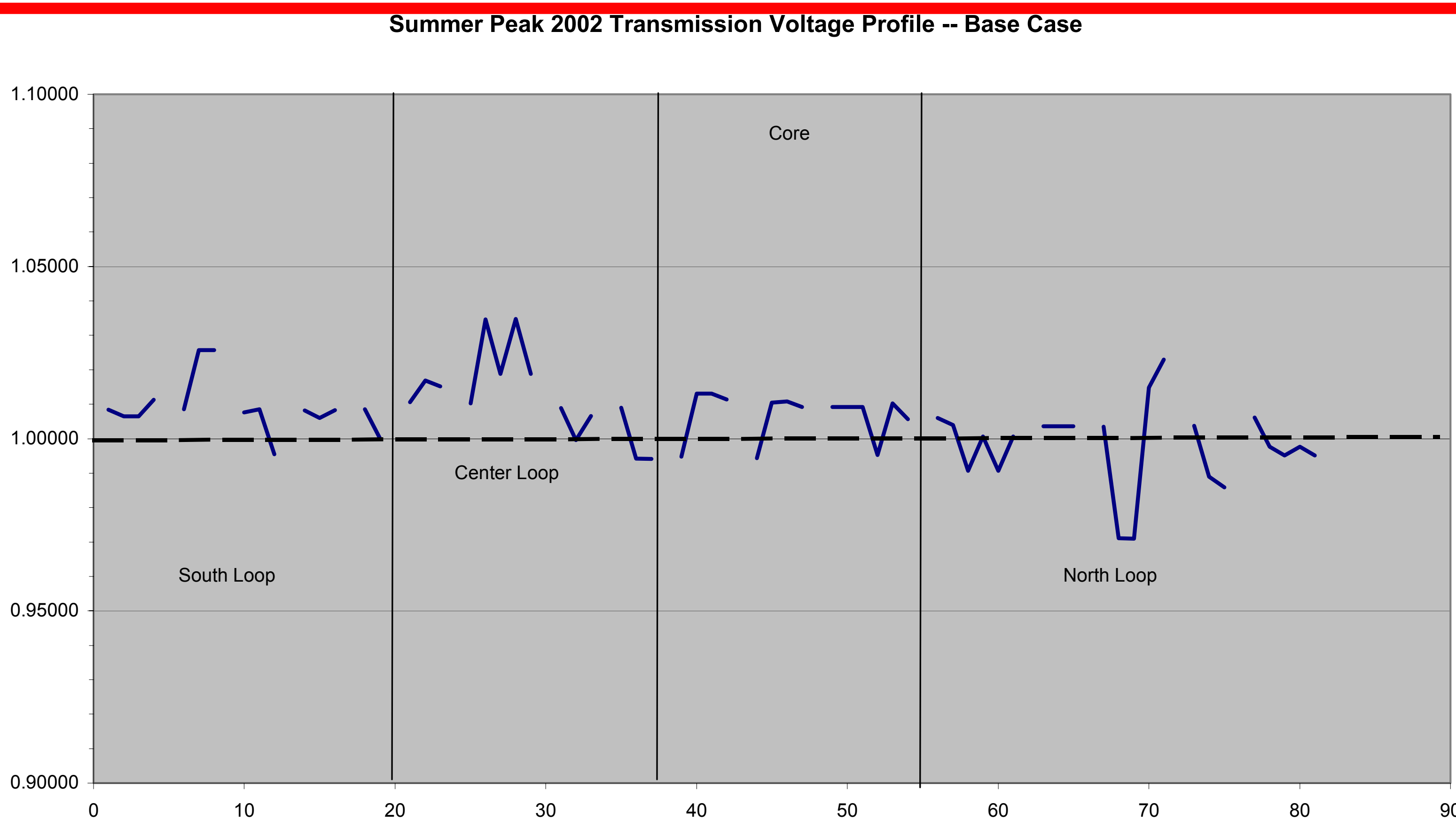
Certain features U.S. Pat. Pend.

Integration of Energynet Dataset

- **Historical Characterization of SVP:**
  - WECC: Two 115 kV buses with two generators and SVP load split between them.
  - SVP: 80 115 kV and 60 kV buses and with loads on distribution stepdown transformers; generators modeled as negative load

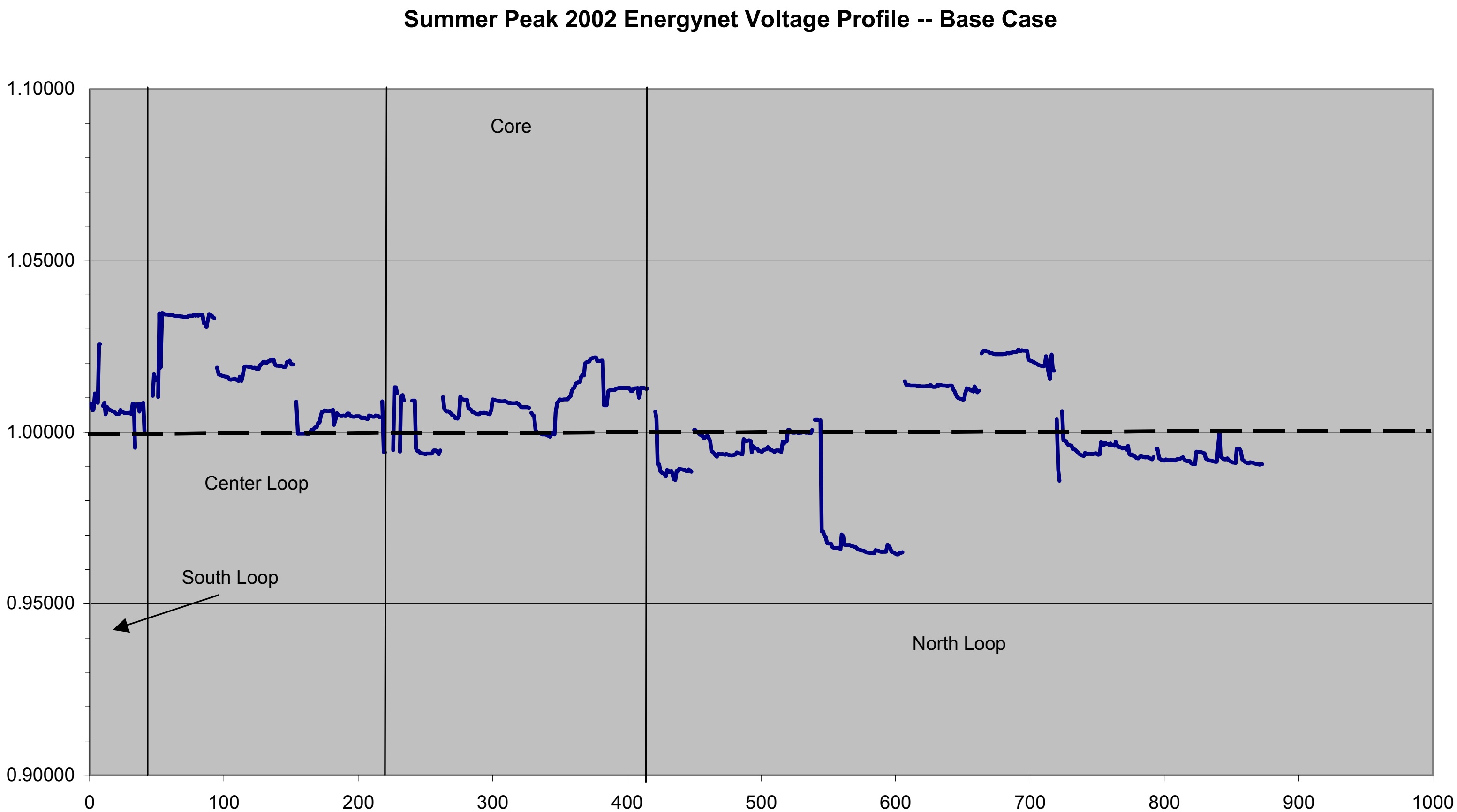
- **Our Characterization of SVP:**
  - ~ 850 bus network -- 115 and 60 kV transmission; 12 kV distribution.
  - 48 12kV distribution feeders connected by 106 switchable branches.
  - 422 load customer-serving buses – customer transformers and customers at primary-voltage service.
  - 6 generators with variable MW and MVAR capacity
  - 101 switchable capacitors.
  - Customer loads and generation from actual 2002 SCADA records.
  - Fully-integrated into PG&E regional 115 kV and 230 kV transmission and ~13,000 bus WECC west-wide high-voltage transmission system.

Summer Peak 2002 Base Case -- Transmission Only



- **All buses within +/- 5% of rated voltage under Summer Peak conditions– a healthy system.**
- **Customer-sponsored generation and demand response would not be connected at these buses.**
- **Distribution-level DER impacts invisible.**

Summer Peak 2002 Base Case Results



- Far more detail.
- Integrating distribution identifies more low-voltage buses and voltage variability.

Improving Delivery Network Performance Using DER

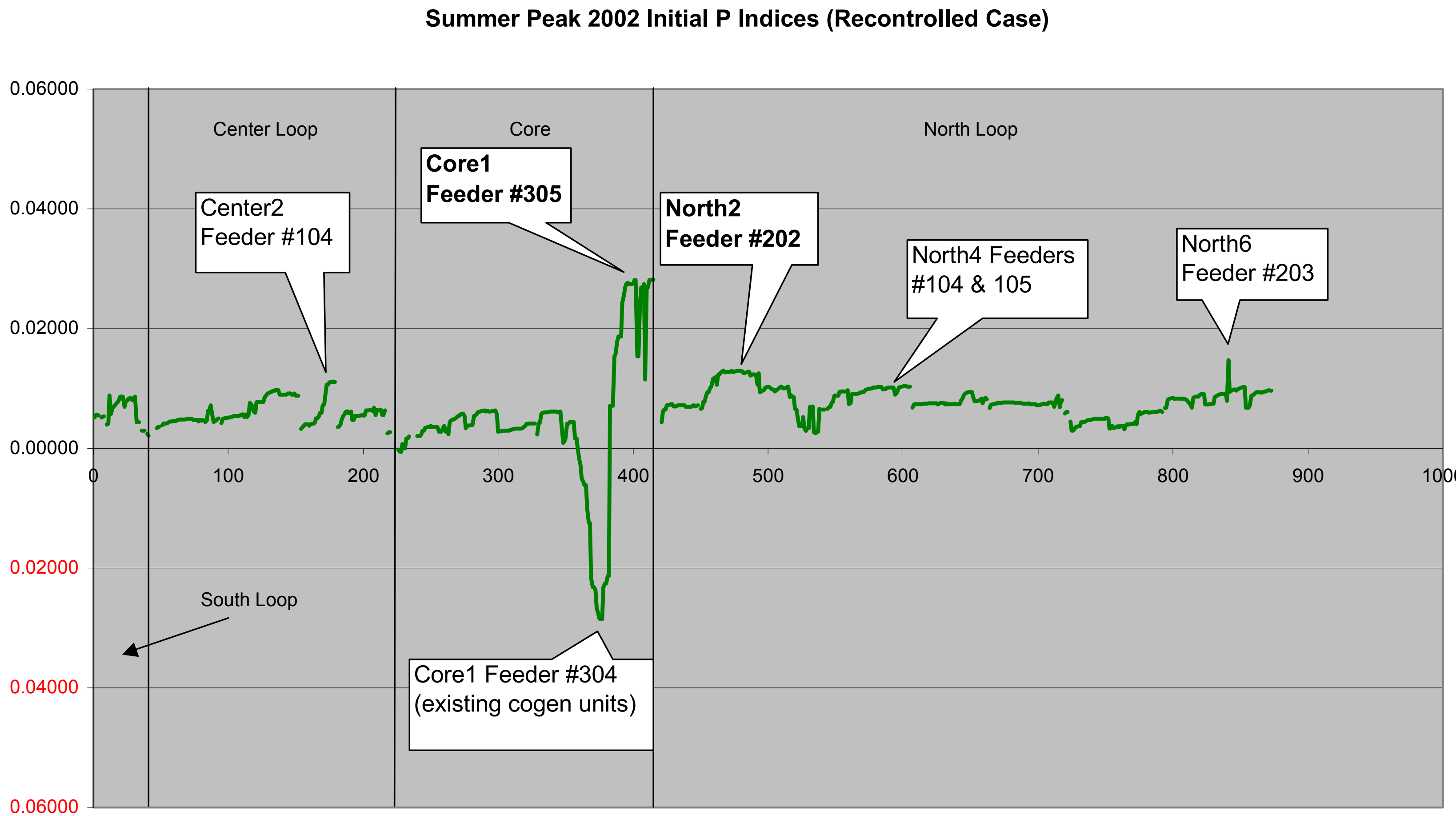
- **Objective:**
  - Minimize real power losses and reactive power consumption while eliminating low-voltage buses and making overall voltage profile "flatter."
- **Existing Controls:**
  - Set MVAR output from shunts and MW and MVAR output from existing embedded generation for the best network performance.
- **Reactive Capacity Additions (MVAR)**
  - Station capacitors and line capacitors in standard sizes.
- **Demand Response Additions (negative load, or MW + MVAR at load's pf)**
  - Limited to 2-15% of customer load depending on customer size and case.
- **Distributed Generation Additions (MW + MVAR based on synchronous generator pf range)**
  - Limited to 60% of customer load
  - Non-export feeder limits.

Assessing the Base Performance of the Delivery Network

- **“Hand” Analysis of Power Flow Results:**
  - Low-voltage buses, sectors with high voltage variability
  - High real and reactive power flow
  - Real and reactive power flowing in opposing directions.

- **AEMPFAST Analysis:**
  - Identifies ideal control variable settings.
  - Calculates “indices” for each bus showing buses where real or reactive capacity additions yield the greatest network-wide improvement relative to the objective.

Adding DER Capacity Using AEMPFAST®



- **P Index identifies locations where adding P capacity is the most beneficial for the "objective" of improved network performance.**

Summer 2002 Case DER Capacity Additions - DR

- **DR capacity addition at 382 locations ranked in terms of network benefit, totaling 13.6 MW.**
- **Top 20 ranked locations for DR capacity addition:**

Rank	Bus No.	Load Name	Location		Load (kW)	DR (kW)	DR Share
1	524	35L12K1	Core1	Feeder 305	192	29	15%
2	5163	35LX300	Core1	Feeder 305	14	2	15%
3	8205	35LX500	Core1	Feeder 305	24	4	15%
4	9129	35LX1000	Core1	Feeder 305	48	7	15%
5	8701	35LX1500	Core1	Feeder 305	72	11	15%
6	8923	35LX500	Core1	Feeder 305	24	4	15%
7	8404	35LX500	Core1	Feeder 305	24	4	15%
8	7285	35LX225	Core1	Feeder 305	11	2	15%
9	8661	22AX1500	North2	Feeder 202	372	56	15%
10	5185	22AX1000	North2	Feeder 202	248	37	15%
11	503	22A12K1	North2	Feeder 202	991	149	15%
12	8313	22AX500	North2	Feeder 202	124	19	15%
13	5178	22AX500	North2	Feeder 202	124	19	15%
14	8630	22AX300	North2	Feeder 202	74	11	15%
15	8662	22AX1500	North2	Feeder 202	372	56	15%
16	5225	22AX300	North2	Feeder 202	74	11	15%
17	5028	22AX500	North2	Feeder 202	124	19	15%
18	8271	22AX300	North2	Feeder 202	74	11	15%
19	8314	22AX500	North2	Feeder 202	124	19	15%
20	8690	22AX750	North2	Feeder 202	186	28	15%

Summer 2002 Case DER Capacity Additions - DR

- **Key feeders among top 100-ranked DR capacity additions:**

Substation	Feeder	Buses/Projects	Total DR (kW)
North2	Feeder 202	20	673
North4	Feeder 104	19	287
North2	Feeder 203	12	531
North6	Feeder 203	10	452
Core1	Feeder 305	8	61
North4	Feeder 105	6	247
North6	Feeder 205	6	314
Center3	Feeder 303	6	139
North4	Feeder 101	5	159

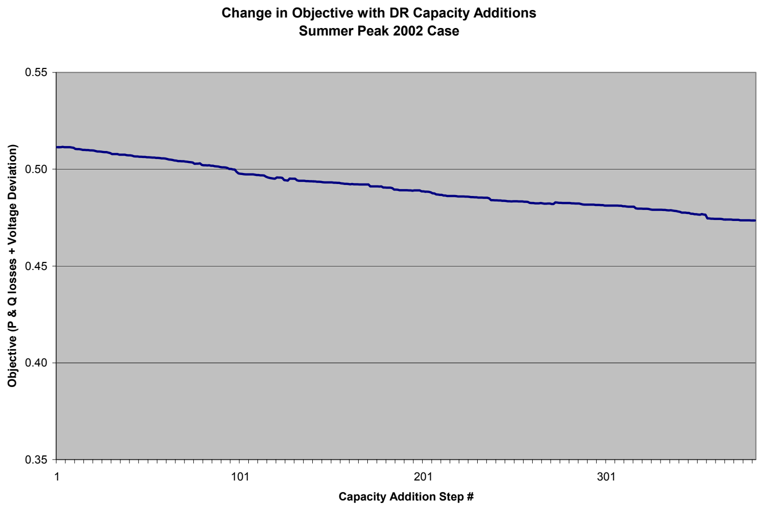
Summer 2002 Case DER Capacity Additions - DG

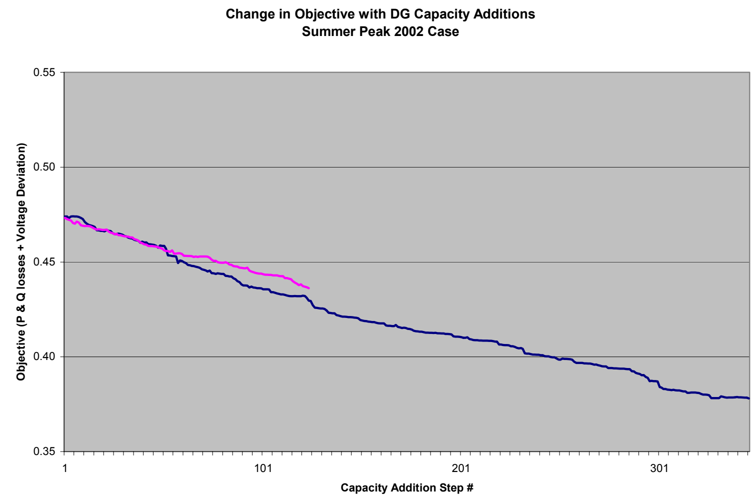
- **DG Additions:**
  - Rule 21 non-export feeder limit: 124 locations totaling 13.8 MW.
  - "Light Load" non-export feeder limit: 346 locations totaling 38 MW.

- **Top DG capacity addition locations (light load feeder limit):**

Rank	Bus No.	Load Name	Location		Load kW	DG kW	DG Share
1	524	35L12K1	Core1	Feeder 305	192	98	51%
2	5163	35LX300	Core1	Feeder 305	14	7	50%
3	8205	35LX500	Core1	Feeder 305	24	12	50%
4	9129	35LX1000	Core1	Feeder 305	48	24	50%
5	8701	35LX1500	Core1	Feeder 305	72	37	51%
6	8923	35LX500	Core1	Feeder 305	24	12	50%
7	8404	35LX500	Core1	Feeder 305	24	12	50%
8	7285	35LX225	Core1	Feeder 305	11	6	55%
9	8661	22AX1500	North2	Feeder 202	372	190	51%
10	5185	22AX1000	North2	Feeder 202	248	126	51%
11	503	22A12K1	North2	Feeder 202	991	505	51%
12	8890	22AX2000	North2	Feeder 202	496	248	50%
13	8854	14WX225	Center2	Feeder 104	508	259	51%
14	7606	15TX112	North4	Feeder 105	34	20	59%
15	7645	23CX225	North6	Feeder 203	80	41	51%
16	8228	15TX750	North4	Feeder 105	231	118	51%
17	504	23A12K1	North2	Feeder 203	776	396	51%
18	7654	23CX225	North6	Feeder 203	80	41	51%
19	8527	14TX300	North4	Feeder 104	35	18	51%
20	5176	14TX225	North4	Feeder 104	26	13	50%

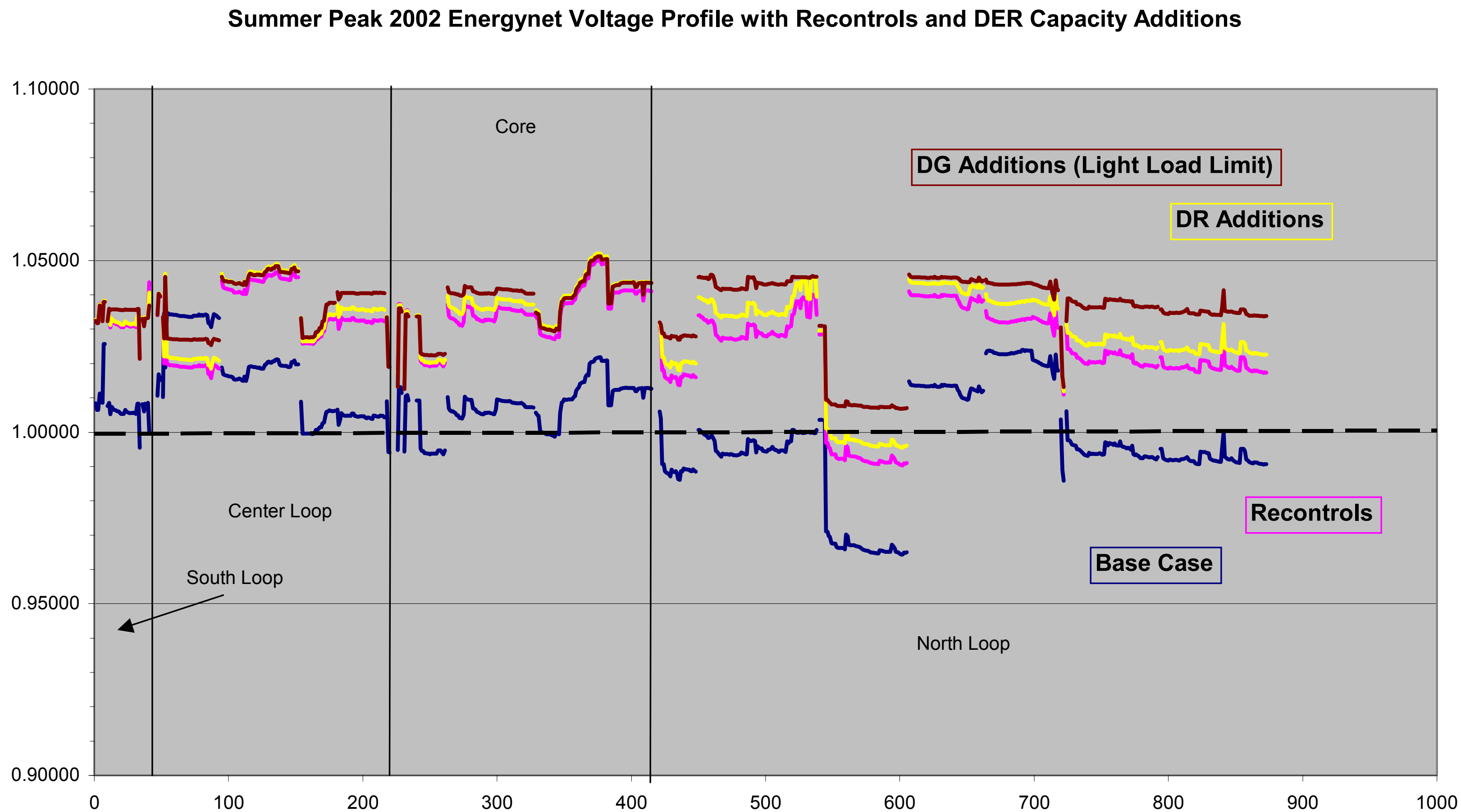
Network Improvement from DER Capacity Additions





- **Sequential DER capacity additions yield cumulative improvement in network performance, indicated by quantified "objective."**
- **DR capacity additions reduce losses by about 11% (0.141 MW)**
- **DG capacity additions reduce losses by about 20% (0.257 MW) under light load feeder limit.**

Voltage Profile Effects from DER Capacity Additions



- **Voltage Profile with DER capacity additions –Flatter and Higher.**

Combined Impact of DER Capacity Additions

- **Dispatchable Demand Response**
  - 382 customer sites totaling 13.6 MW (3.4% of total peak load)
  - Limited to 15% of site's peak load under Summer Peak conditions
- **Onsite Generation**
  - 346 customer sites totaling 38 MW (9.7% of total peak load).
  - Limited to 60% of adjacent load and Light Load "no-export" feeder limit
- **Network Benefits**
  - 31% reduction in P losses in SVP (0.398 MW).
  - 30% reduction in Q consumption in SVP (15.203 MVAr).
  - Losses reduced at 3 x system's average loss rate.
  - ~ 5 MW additional reduced losses in surrounding PG&E system.
  - Low-voltage buses (< 1.000 PU) eliminated.
  - Reduced variability in SVP system voltage profile

What are network benefits of DER worth?

- **Easily Priced:**
  - Reduced need for energy to make up for real power losses.
  - Reduced need for reactive capacity.
  - Increased load-serving capability where network improvements would otherwise be needed.

- **Important but harder to value:**
  - Elimination of low-voltage buses or sectors.
  - Reduced reactive power flow.
  - "Flatter" voltage profile for greater stability.
  - More network flexibility, reduced impacts of contingencies.

Conclusions

- **DER additions can reduce losses *and* improve voltage profile in an integrated power delivery network.**
- **These impacts are real and can be quantified and priced.**
- **Where DER is placed in the network *is* important.**
- **Most impacts of DER (good and bad) would be invisible in a transmission-only analysis.**
- **These methods and tools can identify ways to further optimize even a "healthy" network using DER.**

Challenges to Realizing the (Network) Benefits of DER

- **Assessing and pricing network benefits of DER -- an important first step.**

1. **Financial incentives for network operators (utilities).**
   - Direct financial incentive to improve network performance (e.g. Performance-Based Pricing).

2. **Financial incentives for network operators (utilities).**
   - Equal financial incentive to improve network performance through third-party-sponsored nonwires solutions (e.g. DER) as through utility-sponsored capital additions to the network.

3. **Financial incentives for network operators (utilities).**
   - Financial benefit from large-scale deployment of customer-sponsored generation.

Details

- **500-01-039 Project Participants**
  - New Power Technologies
  - Cupertino Electric, Inc.
  - Silicon Valley Power
  - Optimal Technologies (USA), Inc.
  - Rita Norton & Associates LLC
  - Silicon Valley Manufacturing Group
  - William M. Stephenson
  - Roy C. Skinner
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  - Laurie Ten Hope (CEC Program Area Lead)

- **Technical Advisory Committee**
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  - Jim Kavicky, Argonne National Lab
  - Don Kondoleon/Demy Bucaneg, CEC
  - John Monestario, PG&E Distribution Engineering (retired)

About New Power Technologies

- **New Power Technologies identifies and develops businesses and technologies enabling an intelligent energy infrastructure.**

- **Our core belief is that the electric power infrastructure of the future is an Energynet[SM] comprised of:**
  - Integrated transmission and distribution
  - Embedded (or "distributed") generation with remote generation
  - Loads responsive to network conditions
  - Energy services mass customized to meet customer needs

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